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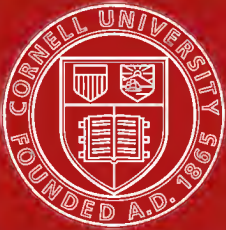
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92 S. E.

MEMOIRS OF THE GEOLOGICAL SURVEY

ENGLAND AND WALES.

EXPLANATION OF QUARTER-SHEET 92 S. E. OF THE GEOLOGICAL MAP
OF ENGLAND AND WALES,

ILLUSTRATING

THE GEOLOGY

OF

THE COUNTRY BETWEEN BRADFORD AND
SKIPTON.

BY

J. R. DAKYNS, M.A.; C. FOX-STRANGWAYS, F.G.S.;
R. RUSSELL, F.G.S.; AND W. H. DALTON, F.G.S.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE,
AND SOLD BY

LONGMAN & Co., Paternoster Row; TRÜBNER & Co., Ludgate Hill;
LETTS & Son, 33, King William Street;
EDWARD STANFORD, 55, Charing Cross; and J. WYLD, 12, Charing Cross:

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Messrs. JOHNSTON, 4, St. Andrew Square, Edinburgh;
HODGES, FOSTER, & Co., 104 Grafton Street, and A. THOM & Co.,
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Price Sixpence.

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NOTICE.

THE area described in the following pages, and comprised in Quarter-sheet 92 S.E. of the Geological Survey Map of England and Wales, contains the N.W. corner of the great Yorkshire Coalfield and its fringing belt of Millstone Grit, the entire width of which, with a portion of the Carboniferous Limestone series, is exposed between Skipton and Bradford.

The area is fully described in the larger Survey Memoir on the Yorkshire Coalfield, where details are given that are not repeated here.

The western portion of the Map was surveyed by Messrs. DAKYNS and DALTON, a narrow slip along the western edge being mapped by Mr. GUNN.

The whole of the south-western portion of the quarter-sheet was surveyed by Mr. DAKYNS.

The eastern part of the Map was surveyed by Messrs. RUSSELL and LUCAS who, together with Mr. FOX-STRANGWAYS, also mapped the Coal-Measures. Besides the Coal-Measure area situated north and west of Bradford, surveyed by Mr. FOX-STRANGWAYS, the great mass of hills occupying the central portion of the Map (and extending from Thornton through Bingley and Ilkley Moor) and the country lying to the north of Slingsby, were also mapped by him.

Each of the above-named has described the parts of the district for the mapping of which he is responsible, and Mr. Russell has acted as general editor of the Memoir.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, S.W.
20th November 1879.

G E O L O G Y

OF THE

COUNTRY BETWEEN BRADFORD AND SKIPTON.

THE description which is given in this pamphlet, is simply a brief account of the chief features in connection with the geology of the district, as delineated on the Quarter-Sheet 92 S.E., of the One-inch Map of the Geological Survey of England and Wales. Details will be found in the larger Memoir on the Geology of the Yorkshire Coal-field, published in 1878.

The rocks comprised within this area, excepting the Post-Tertiary beds, consist entirely of Carboniferous rocks, ranging from the Upper Limestone Shales to the upper beds of the Lower Coal Measures. The Lower Coal Measures occupy the southern portion, and form part of the most northerly extension of the Yorkshire Coal-field. Nearly the whole of the remaining part of this tract is occupied by the various members of the Millstone Grit Formation. The Upper Limestone Shales rise from beneath these beds in the north-west only, near Skipton. To the south and south-west the measures have a general north and south strike, but before entering our present district they begin to bend round, and finally range across the country from Kildwick to Poole, with an east and west strike and a southerly dip.

The superficial beds consists of the alluvial deposits in the valleys of the Rivers Aire and Wharfe; of Boulder Beds which are also mainly confined to the valleys; and of Esker Gravels, some of which occur at considerable elevations, and some are only found in the present alluvial plains of the main valleys.

The geological structure of the district is complicated, and in many parts very obscure, owing to the variable character of the measures, the number of the faults, the nature of the atmospheric denudation, and lastly, to the presence of Glacial Drift, which, in places, attains a thickness of from 100 to 200 feet.

TABLE OF FORMATIONS IN MAP 92 S.E., AND LITHOLOGICAL
DESCRIPTION OF THE ROCKS.

Table of Formations.

POST TERTIARY	{	Peat.	
		River Deposits	{ Clay, Gravel, and Sand; of various dates.
		Low-Level Esker-Gravel; High-Level Esker-Gravel; Boulder Beds.	
PALÆOZOIC	{	CARBONIFEROUS	{ Lower Coal Measures - Feet. Millstone Grit - 822 Upper Limestone Shales - 3333 2600*

TABLE OF CARBONIFEROUS ROCKS IN MAP 92 S.E.

In Descending Order.				From.	To.	Average.
				ft. in.	ft. in.	ft. in.
LOWER COAL MEASURES.	61. Measures	-	-	-	-	95 0
	60. Crow coal	-	-	1 4	2 0	1 6
	59. Measures	-	-	36 0	42 0	38 0
	58. Ironstone Measures	-	-			
	57. Black Bed coal	-	-	2 4	2 10	2 6
	56. Measures	-	-	104 0	120 0	113 0
	55. Sandstone, THICK STONE.	-	-			
	54. Measures	-	-			
	53. Better Bed coal	-	-	1 2	2 8	1 8
	52. Fireclay	-	{ Ganister 2 0 to 2 6 Fireclay 0 7 „ 4 0 }	-	-	3 0
	51. Sandstone, BETTER BED SEAT-STONE.	-	-	10 0	39 0	27 0
	50. Measures	-	-	-	-	95 0
	49. Sandstone	-	-	-	-	210 0
	48. Shales	-	-			
	47. Sandstone	-	{ GAISEY OR			
	46. Shales	-	{ SIXTY YARDS			
	45. Sandstone	-	{ ROCK.			
	44. Measures containing Sandstone and Galliard bands.	-	-	-	-	65 0
	43. Hard Bed Band coal	-	-	0 4	2 0	0 6
	42. Sandstone, THIRTY-TWO YARDS ROCK.	-	-	30 0	50 0	45 0
	41. Measures	-	-	-	-	-
	40. Hard Bed coal	-	-	1 4	1 10	1 6
	39. Fireclay 3 ft. to 24 in.	-	-	30 0	80 0	50 0
	38. Measures containing Middle Band coal and MIDDLE BAND STONE.	-	-			
	37. Soft Bed coal	-	-	0 8	2 0	1 4
	36. Measures containing Galliard, Band, and Cottingley Crow coal	-	-	50 0	105 0	75 0

* This is simply the thickness of that portion of the Upper Limestone Shale which occurs within the present district.

In Descending Order.		From.	To.	Average.	
		ft. in.	ft. in.	ft. in.	
MILLSTONE GRIT.	35. ROUGH ROCK - - -	—	—	195 0	
	34. Stanbury Moor coal - - -				
	33. { Shale - - - Flagstone - - -				
	32. Shales - - -	—	—	70 0	
	31. Crow Croft coal - 0 0 to 3 0				
	30. Shales - - -				
	29. Sandstone - - -	40 0	55 0	140 0	
	28. Coal - 0 0 to 2 0	55 0	152 0		
	27. Shale - 40 0 „ 20 0				
	26. Sandstone - 67 0 „ 15 0				
	25. Coal - 0 0 „ 1 1				
	24. Shale - 45 0 „ 25 0				
	23. Sandstone. GUISELEY GRIT.	—	—	70 0	
	22. Shale - - -	45 0	60 0	120 0	
	21. Sandstone; probably in three separate beds at Bramhope with intermediate bands of shale. GRIT OF EARL CRAG.	100 0	190 0		
	20. Morton Banks coal - - -	0 0	6 0	3 0	
	19. Shales - - -	40 0	115 0	75 0	
	18. Sandstone; with intermediate shales - - -	50 0	155 0	100 0	
	17. Shales - - -	0 0	70 0	30 0	
	16. Sandstone - - -	75 0	170 0	125 0	
	15. Shales - - -	—	—	440 0	
	14. Sandstone. LEATHLEY SANDSTONE.	45 0	60 0	50 0	
	13. Shales, in the east containing <i>Posidonomya Gibsoni</i> - - -	30 0	75 0	45 0	
	12. Sandstone, WESTON GRIT. - - -	75 0	90 0	80 0	
	11. Shales - - -	20 0	86 0	40 0	
	10. Sandstone - - -	30 0	35 0	32 0	
	9. Shales - - -	20 0	70 0	43 0	
KINDER SCOUT GRIT.	8. Farnhill Moor coal 0 0 to 1 8	—	—	80 0	
	7. Gritstone - - -	—	—		
	6. Low Bradley coal 0 0 to 2 6	—	—	240 0	
	5. Gritstone with High Bradley coal about the middle - - -	—	—		
	4. Shales - - -	—	—	140 0	
	3. Gritstone - - -	—	—	610 0	
PENDLE HILL GRIT.	2. Sandstone and Shales, variable. BASEMENT BED OF THE MILLSTONE GRIT - - -	—	—	600 0	
	1. Limestone Shales - - -	—	—	2600 0	

LITHOLOGICAL DESCRIPTION.

Upper Limestone Shales.—The Limestone Shales, No. 1, consist, from the base to above the highest limestone, of several beds of dark limestone alternating with black shales more or less calcareous. Thin beds of flaggy limestone also occur in these shales. The black shales pass up into black sandy shales, devoid of calcareous matter, upon which rest the grits of Pendle Hill.

Millstone Grit.—The sandstones and Shales No. 2, are the basement-beds of this sub-formation. They consist of rocks which are the equivalents of the grits forming the escarpment of Pendle Hill, facing Clitheroe. Hence we have called them Pendle Hill Grits. They are, also, equivalent to "the shale-grit" of Farey, and retain here the character which induced that geologist to give them such an expressive name.* We find it impossible, satisfactorily, to separate these grits from the overlying beds, and accordingly we take them as the base of the Millstone Grit. These basement-beds consist of sandstones (mostly fine grained) interstratified with numerous bands of shale. Throughout this series the bedding is very irregular. The total thickness of this group is about 600 feet.

The chief portion of the Millstone Grits form here a very different series of rocks from what they do in the country to the south. In Derbyshire this series consists of four or five well-marked grits, separated by shales, viz., the topmost grit or Rough Rock; the second grit, generally a flagstone; the third grit, a bold well-jointed rock; and the Kinder-Scout Grit, which sometimes consists of two beds. In the valley of the Colne we find four separate sandstones between the Rough Rock (locally known as the "Sand-rock") and the Kinder-Scout Grit. This type prevails also in the valley of the Yorkshire Calder, but is not to be found on crossing the watershed into the basin of the Aire, our present district. Here the series consists, in descending order, first, of the Rough Rock, which throughout maintains its usual "rough" character; secondly, of a very variable basement-bed to the last, consisting when well developed of valuable flagstones. These are extensively quarried at Nab, above Oxenhope Moor, and also in an outlier at the Penistone quarries, near Haworth. Below this bed comes a series of variable sandstones and shales. There may be in places as many as 15 or 16 distinct sandstones between the basement-bed of the Rough Rock and the regular Kinder-Scout Grit. But this set of beds may conveniently be divided into two parts by means of a conspicuous grit which is continuous with the third grit of Lancashire. This grit forms the bold escarpment of Hallan Hill, Earl Crag, Addingham Edge, and Otley Chevin. There are generally three grits between it and the Rough Rock; these four beds are presumably the four grits of the Colne and Calder valleys mentioned above.

The Pendle Hill rocks pass up into the Kinder-Scout Grits, Nos. 3, to 14, which also consist of a set of grits separated from

* FAREY, "General View of the Agriculture and Minerals of Derbyshire."

each other by bands of shale. The lower beds are excessively coarse and pebbly, containing pebbles of vein-quartz and occasional sandstone-pebbles, the grains of which are of a peculiarly translucent quartz. Some of the sandstone-pebbles are of precisely the same character as the ordinary carboniferous sandstones. The upper part of the series consists of fine-grained white siliceous flagstones, shale bands, and a few irregular seams of Coal. Excellent material for heavy masonry is obtained from several of the members of this group. The flagstones are used as paving and roofing flags. The irregular Coal seams have been worked along the outcrops at several places. Of these seams, the High Bradley Coal has been largely wrought. The workings are very old, and neither the thickness nor quality of the coal could be ascertained; the Low Bradley Coal, No. 6, is 2 ft. 6 in. thick at Low Bradley, but it speedily thins out, and finally dies away altogether. Another Coal, Farnhill Moor Coal, No. 8, has been proved on Farnhill Moor to be 1 ft. 8 in. thick, but the quality is very inferior, and the seam has never been worked.

No important break occurs north of the River Aire between the Kinder-Scout Grits and the Middle Grits, Nos. 15, to 32. The Shale, No. 15, seems to be much thinner on the north, than on the south, side of Wharfedale.

The Middle Grits are a great series of variable sandstones and shales. The Coal-seams are thin, irregular, and of limited extent. In some places this group is capable of division into eight or nine separate beds of sandstone, in other localities many more subdivisions exist. Any strictly accurate correlation of one bed in the south with another in the north is therefore almost impossible.

West of the Valley of the River Aire, the principal rock of this group is the Grit of Earl Crag, No. 21. On the east the same bed forms the bold escarpments south of the River Wharfe, known as Addingham Edge and Otley Chevin. This grit is probably represented by the Plompton Grit in the country to the north*. In the extreme east of the present district the Addingham Edge Grit seems to split up into the several divisions of the Bramhope Grits. Generally it is a massive and coarse-grained rock. It forms many of the chief features for which the scenery of this district is famous. The rocks both above and below the Addingham Edge Grit are very variable. The sandstones are interlaced with bands of shale, which die out, and reappear in a very capricious manner.

The shales vary from light-coloured sandy shale to black bituminous shale. Limestone nodules occur on one horizon in these beds near Silsden. The texture of the grits varies from fine-grained white sandstone, highly silicious and resembling statuary marble, to coarse yellow grit. The grits are seldom, if ever, pebbly in character. In structure they range from massive rock to fine thin-bedded flagstone. Building stone, suitable for all classes of masonry, is obtained from these sandstones. The

* Explanation of Quarter-sheet 93 N. W., page 7.

chief use, however, to which they are applied at present is for road-metal; for this purpose the highly silicious beds are well adapted.

Like all the coals of the Millstone Grit series, the character of the seams existing in this group is very variable. The Morton Banks Coal, No. 20, is in some instances as much as 6 feet in thickness. This Coal has been worked to some extent on the north side of the Aire valley, south of Silsden Moor. A coal band, 1 ft. 6 in. thick, occurs on Oxenhope Moor, in the extreme south-west of the present district. It lies nearly on the same horizon as the Morton Banks Coal. The Coal, No. 25, is a seam 1 ft. 8 in. thick at Haworth. Its range is very limited. Another Coal, No. 28, has been worked on Silsden Moor, and also north of Baildon Common. The maximum thickness is 2 feet. At Silsden it underlies a thin band of sandstone, No. 29, the highest sandstone bed of the Middle Grit Series.

Some bands of Coal occur in the Shales, Nos. 30, to 32, which lie between the topmost sandstone of the Middle Grits and the Rough Rock. The chief of these coal-bands is the Crow Croft Coal, No. 31. A coal which in the neighbourhood of Keighley ranges from 8 inches to 2 feet thick, may be equivalent to this seam. At Crow Croft, north of Idle, the thickness is 2 feet. Here the quality of the coal is good. In some cases the thickness reaches 3 feet. West of Keighley the above mentioned shales contain *Goniatites* and other fossils.

The distinguishing characteristic of the Rough Rock or Upper Grit, Nos. 33, to 35, is a thick mass of coarse grit with beds of a more or less flaggy character at the base. In the west of the area now under consideration, the Middle Grit Shales are overlaid by a peculiar blue sandstone, known as "The Blues." These beds may be seen in a quarry near the Tarn, two miles north-west of Keighley. Similar beds, believed to be on the same horizon, are seen near Hare Hill above the Colne and Keighley road. "The Blues" seem to be a peculiar form of the basement-beds of the Upper Grit, as they are overlaid by a coarse crumbly grit, which both lithologically and stratigraphically corresponds to the Rough Rock.

The Blue Stone appears to lose its distinctive character both westwards and eastwards from Hare Hill, and is seemingly replaced by ordinary flagstone. The Flags, No. 33, are excessively variable in their occurrence. They are well developed at Nab, Oxenhope Moor; at Penistone Quarries, on the top of the high ground south of Haworth; and at Gilstead Moor, east of Bingley. In some form or other these flaggy beds exist throughout the whole of the district between Baildon and Horsforth, and in numerous instances attain a very considerable thickness.

"The Blues" are mainly used as road metal. The Flagstone is largely quarried, and yields paving and roofing-flags of excellent quality. The Grit, No. 35, forming the upper portion of the Rough Rock occurs occasionally in one bed, as in the south of this district; but more frequently it is divided, by thin shale bands,

into two or more beds, each of which makes a slight feature on the ground. These beds are generally very coarse-grained, but towards the east their texture is somewhat finer. The coarse grits are composed to a great extent of vein-quartz, but they also contain pebbles of chert and slightly-rolled crystals of felspar. The decomposition of the felspar often renders the rock crumbly. Sometimes, however, the felspar is found quite crystalline, even in the pebbles protruding from weathered surfaces.

This grit yields stone of great value for heavy works, such as harbour walls, engine beds, and, in fact, every other purpose for which massive and durable stone is required. The best qualities of the rock are exceedingly durable. The smoky atmosphere of the manufacturing towns does not affect it to any serious degree.

Lower Coal Measures.—The group, No. 36, contains the Cottingley Crow Coal and the Soft Bed Seat-stone or Galliard. This Coal Band is only 4 inches thick, and lies about 10 yards below the Soft Bed Coal; the Seat-stone is a close, finely-grained, hard sandstone, which in the upper portion closely resembles a ganister. The rock is thin and occasionally altogether absent.

The Soft Bed Coal, No. 37, has been worked rather extensively in the country north of Bradford, and between Denholme and Horsforth. About Denholme and Baildon the coal is 1 ft. 6 in. thick. East of Idle the thickness increases locally to 3 ft. At Rawden it was only 10 ins., and at Horsforth not more than 8 ins. thick. The quality of this seam is poor and rather inferior.

No. 38, includes the Middle Band Stone, which hardly calls for special notice, and the Middle Band Coal from 1 in. to 6 in. thick. The continuation of the Middle Band Coal is only known from the fact that it has been proved in the sinkings at Thornton and Baildon.

No. 39, is the Fireclay underlying the Hard Bed Coal. The very valuable ganister of the Halifax district does not exist along the north-western edge of the coal-field unless at Thornton, where there is a thin bed of ganister under the coal. In the neighbourhood of Thornton the fireclay and underlying shale is 15 feet thick. At Baildon the clay attains a thickness of 24 feet. Between Heaton and Horsforth it ranges from 6 ft. to 3 ft., and is largely wrought for the manufacture of bricks and tiles.

The Hard Bed Coal, No. 40, is the more important of the two Halifax Coals, and has been very generally worked throughout the district, partly for the sake of the coal itself, and partly on account of the valuable fireclay, No. 39, which underlies the coal. North of Denholme the coal is only 1 ft. thick. Between Thornton and Idle the average is 2 ft.; and between Baildon and Horsforth it varies from 1 ft. 4 in. to 1 ft. 8 in. in thickness.

No. 42 is a thin band of sandstone, which in the neighbourhood of Denholme, underlies the underclay of the Hard Bed Band Coal. As the 32-Yards Rocks of Stanningley and Rawden it becomes a sandstone of some importance. It is regularly bedded and

finely-grained. In places some portions of it approach the nature of ganister.

The Hard Bed Band Coal, No. 43, in the vicinity of Denholme, attains a thickness of 2 ft., and has been worked. In the country to the eastward, it is generally from 4 in. to 9 in. thick, but in some instances there is only a trace of carbonaceous matter on the top of the 32-Yards Rock.

The Elland Flagstone Group, Nos. 44, to 49, includes all the principal sandstones which lie between the Hard Bed Band and Better Bed Coals. Around Thornton the "Sixty-yards Quarrell" is separated from the main mass of the flagstone by a thick bed of shale. To the east of Thornton the shale seems to thin away, and the two sandstones apparently unite and constitute a thick and massive rock at Gaisby, north of Bradford. The "Sixty-yards Quarrell" is a name derived from the fact, that in the west and south-west, this sandstone lies about 60 yards above the Hard Bed Coal. North and north-east of Bradford the distance between the Gaisby Rock and Hard Bed Coal is greater than 60 yards. The texture of the sandstone is coarse and gritty, in this respect resembling some of the rocks of the Millstone Grit series. Stone suitable for a variety of building purposes is obtained from this sandstone.

The sandstones (Nos. 47, and 49,) represent the Flagstone of Thornton, which is the more important rock of this group in that locality. The flagstone is frequently divided into several beds by thin bands of shale, but occasionally occurs as one thick continuous mass of sandstone. The lower portion is often shaly and inferior; the celebrated flagstones known as "Yorkshire Landings" are obtained chiefly from the middle division; and the upper beds of the flagstone are mainly distinguished for the roofing-slates which they yield.

No. 52, is the celebrated Fireclay of Wortley. The Ganister occurs only in the district around Laister Dyke, and is from 2 ft. to 2 ft. 6 in. thick. The Fireclay ranges from 7 in. to 4 ft. in thickness. It is of excellent quality, and suitable for the manufacture of all articles in which fireclay is employed.

The Better Bed Coal, No. 53, varies from 1 ft. 2 in. to 2 ft. 8 in. The extent of this seam within the present area is very limited, and the coal has been mostly wrought out. The quality was equal to that of the same seam in the Low Moor and Hunsworth districts.*

No. 55, is generally a thin, and in places a shaly, band of sandstone. It is chiefly of importance owing to the fact, that under some form or other, it exists along the whole of the northern edge of the coal-field.

The Black Bed Coal, No. 57, has a thickness of from 1 ft. 10 in. to 2 ft. 5 in. Wherever the coal is present it has been much sought after on account of the overlying ironstone-bearing shale, and is now practically worked out.

* Explanation of Quarter-sheet 88 N.E. (Memoirs of the Geological Survey), page 5.

The Ironstone Measures, No. 58, in the neighbourhood of Bradford and Farnley, were the first sources from whence the Bowling Iron Company, Limited, and the Farnley Iron Company, Limited, obtained the ore for the manufacture of the famous Bowling, Low Moor, and Farnley Iron. The ironstone contains comparatively a small percentage of metallic iron.* Owing, however, to the skill displayed in the processes of manufacture the iron produced is justly celebrated for its toughness and ductility.

The following section shows the general character of the measures from which the richest portion of the ore was obtained at Bradford:—

			ft. in.	ft. in.
Black shale and ironstone	-	-	-	4 11½
Black shale	-	-	-	1 0
Ironstone	-	-	0 1½	
Black shale	-	-	-	0 6
Ironstone	-	-	0 1½	
Black shale	-	-	-	0 9
Ironstone	-	-	0 2½	
Black shale	-	-	-	1 4
Ironstone	-	-	0 4	
Black shale	-	-	-	0 9
Ironstone	-	-	0 1½	
Black shale	-	-	-	1 0
Ironstone	-	-	0 1	
Black shale	-	-	-	0 6
			1 0	10 9½

The Crow Coal, No. 60, is the highest seam of workable coal which occurs within the present area. It is a bright, tender, friable, caking, and bituminous coal. As a soft coal for gas-making the quality is good. The section is as follows:—

Coal	-	-	-	-	ft. in.	ft. in.
					1 0'	1 5
Underclay	-	-	-	-	0 3	1 6
Coal	-	-	-	-	0 1½	0 6

Boulder Beds.—A large portion of this tract of country is thickly covered with Glacial Drift. This consists of Till, a confused mixture of clay and stones, the latter consisting entirely of Carboniferous Rocks; amongst them is a goodly percentage of limestone-pebbles, all well-scratched, showing that the materials of which it is composed have come from the west and north. The same direction is indicated by glacial striæ on the grit south-east of Keighley, which point up the valley of the Aire. The Till is found to be more abundant on the north and west sides of valleys than on the south or east; that is on the lee sides with reference to the source of the material.

It is, moreover, entirely confined to the country north of the Aire and Calder watershed, having nowhere crossed the ridge of land, 1,350 feet above present sea-level, forming that watershed.

* Iron Ores of Great Britain (Memoirs of the Geological Survey), Part I., page 31.

High-Level Esker Gravel.—Deposits of sand and gravel, distinct from ordinary River Gravel and Eskers, overlie the Till at various places, most of which are several hundred feet above the sea-level. A small patch of sand and gravel occurs near Hare Hill, at a height of 1,025 feet.

The age of this gravel is very doubtful.

On the high ground above Ilkley and Burley, known as Burley Moor and Hawkesworth Moor, and also at several other places, occur curious ridges of gravel. The origin of these ridges is uncertain. They partake more of the character of the Irish Eskers than anything else, we therefore class them as High-Level Eskers. These ridges are composed of limestone boulders mixed with pebbles and sand. They usually have the form of a long ridge, or rather a succession of long mounds. Their maximum width is about 60 yards and the height 10 or 20 feet above the surface of the ground.

These Eskers commence nearly due south of Ilkley, at an altitude of 1,175 feet, and range first in an easterly and then southerly direction to the village of Hawkesworth, where they terminate at an elevation of only 600 feet above the sea. They run obliquely across the slope of the ground, and do not appear to have any relation to the neighbouring features. They lie partly on Boulder Clay and partly on ground free from this deposit.

Low-Level Eskers.—Mounds of water-worn gravel and sand enclosing hollows, occur along the Valley of the Aire below Keighley. These gravels, though much rounded, nevertheless contain pebbles which still retain faint traces of ice-scratching. The Eskers or Kames bear a distinct relation to the principal valleys, in which they form irregular mounds at certain points only, and in which alone they are found.

The gravel mounds near Bingley, may probably have formed part of the moraine of a glacier which descended Airedale. They more or less fill the bottom of this valley between Bingley and Shipley, and also the tributary valley of Harden Beck. At Bingley the thickness of this gravel is over 100 feet.* Here they form a barrier across the river, and the valley above this place appears to have formerly been occupied by a lake. Large quantities of decayed wood, nuts, &c., have been found in the alluvium hereabouts. Between Shipley and Bingley another barrier formed by these gravels completely dammed up the river, which afterwards cut a new channel for itself through the solid sandstone on the north.

River Deposits of the Aire and Calder.—Terraces of sand, gravel, and clay, occur along the present alluvial plains of the main valleys. A very well-marked terrace, about 25 feet above the present river-flat, exists throughout nearly the whole of the

* A. TYLOR, Quart. Journ. Geol. Soc., vol. xxv., p. 63.

Valley of the River Wharfe from Addingham eastwards through Ilkley, Otley, and Poole.

In the Aire Valley a similar terrace, from 10 to 15 feet above the level of the recent alluvium, is found at various places north and east of Keighley, south of Baildon, and between Upper Esholt and Newlay.

The modern alluvium occurs in a series of flats, of greater or less breadth, at a very slight elevation above the present level of the rivers.

Peat.—Several small patches of peat not exceeding 6 feet in thickness occur on Ilkley Moor.

Peat also occurs on Keighley, Stanbury, and Oxenhope Moors.

(2.) PHYSICAL FEATURES AND DRAINAGE.

The physical features of this country correspond roughly to the two principal lithological divisions into which the Carboniferous Rocks are naturally divided, viz., Millstone Grit and Lower Coal Measures. Unless where the ground is obscured by Drift, and the Drift occurs mainly in the valleys, the terrace-like escarpments of the Millstone Grit area are very conspicuous. The coarse and massive sandstones of this series form rugged uplands and broad extensive moors. In general, the physical structure might be regarded as that of an immense plateau, sloping gently to the south and intersected by numerous valleys, whose streams have carved out the sloping plateau into lofty terraced ridges, and flat-topped hills. Some of these ridges rise to a height of from 1,300 to 1,500 feet above the sea-level.

The thick sandstones of the Lower Coal Measures also impart considerable variety to the scenery in the southern part of the district. The elevation of this tract above the sea rarely exceeds 950 feet.

Over a part of the western portion the dip is to the east of south, but the measures speedily bend round, and in the northern and south-eastern portions of the area the dip is almost due south. The great escarpments of the Earl Crag Grit, south of Ilkley and Otley, mark out the general line of east and west strike very distinctly.

Nearly the whole of the drainage flows into the two great catchment-basins of the Rivers Aire and Wharfe. The only exception is a small tract of country comprised in the S.W. part of the map and situated south of the water-shed between the Rivers Aire and Calder, which is drained by some of the small tributaries of the Yorkshire Calder. Both the main rivers enter the district from the north, and cut through the millstone grit escarpments in a south-easterly direction. The Wharfe is, however, deflected by the escarpment south of Addingham, and that river flows from thence eastwards, nearly parallel to the direction of that very striking and bold feature.

(3.) GEOLOGICAL STRUCTURE.

The Upper Limestone Shales occur near Skipton in the extreme north-west corner of the district. These shales are much contorted and their dip is often vertical.

A small triangular area, bounded on the south by an important fault, is occupied by calcareous shales containing the Carlton Limestone. South of that fault the limestone occurs in an anticlinal ridge, and is the lowest rock seen. The shales dip at high angles on both sides of the limestone anticlinal. On the south-east they pass under and are overlaid by the lowest member of the Millstone Grit Series.

The Pendle Hill and Kinder-Scout Grits enter the district south of Skipton with a steady north-east strike. The lowermost grit consists of a mass of sandstones and shales which become very concretionary near the bottom. The Kinder-Scout Grit west of the Aire, consists of three well-marked beds, the two lowest being coarse grits, and the highest a grit overlaid by a peculiar fine white close-grained flagstone which forms the hill-side west of Cononley. These beds seem to be thrown up on the S.E. by a N.E. fault south of Cononley, so that the lowest member of the Kinder-Scout Series forms Cononley and Farnhill Moors. These beds are then thrown down on the S.W. by a N.W. fault, which is part of a fracture that has been traced from the coal-measures west of Bradford. Lead-ore is got in this fault and in strings connected with it on Cononley Moor. The two grits mapped on Glusburn Moor, on the down-throw side of this fault, though certainly above the Kinder-Scout Grit of the country to the west are yet more closely connected with that rock than with the beds above. We have therefore classified these beds as part of the Kinder-Scout Grit Series. There is no conspicuous bed of grit south of the Glusburn below the Crag Side Rock. On the north and east sides of the Aire it is somewhat uncertain what ought to be taken as the top of the Kinder-Scout Grit, though there is no doubt about the main mass of the bed. This well-marked coarse and massive grit strikes east and west along Skipton and Draughton Moors, crosses the River Wharfe near Farfield, and rises to the summit of Beamsley Beacon, just beyond the area now under notice. Westward from Addingham, members of the Kinder-Scout Grit group occupy nearly the whole of the country north of the River Wharfe.

West of Airedale the lowest member of the Middle Grits is found just above Crag Side, west of Sutton; above it comes on the rock forming the bold feature of Earl Crag. These two grits are together equivalent to the Third Grit of Lancashire, and the Chatsworth Grit of Derbyshire. Between Earl Crag and the Aire Valley, these beds are intersected by several faults, but they can be identified throughout the whole district by the massive character of the upper bed. From the conspicuous escarpment of Earl Crag, the chief rock of this group runs eastward; forms the striking ridge south of Sutton and Steeton; crosses the valley of

the River Aire near High Utley; rises again on the east side of the valley to White Crag, in which space the escarpment is traversed by several faults; and then stretching eastwards along Addingham Edge and Otley Chevin forms the one grand, yet ever varying, feature which distinguishes this portion of the scenery of Wharfedale.

Turning once more to the western portion of this upland country, the Rough Rock occupies isolated patches and crowns the tops of some of the highest ridges west of the Worth valley. A fault with a large upthrow to the south runs from Thornton Lane End through Leeming and across Stanbury Moor along Withins Slack. The beds lying on the south side of this fault are members of the Middle Grits, with the exception of the flagstone of Nab on Oxenhope Moor, 1,473 feet above the sea, and two little patches of Lower Coal Measures at the southern edge of the map. The flagstone of Nab is the base of the Rough Rock. North of the fault above mentioned the Rough Rock occurs on Stanbury Moor, its base running round above Upper Ponden. The Rough Rock also forms the greater portion of Keighley and Oakworth Moors, and is thrown out on the north by the fault which ranges through Cullingworth and Oakworth to Sutton Moor. The basement-beds, "the Blues," are found on the high ground at the Tarn, north-west from Keighley. Crossing to the east of the valley of the Worth, the escarpment of the Rough Rock forms the conspicuous feature at Black Moor, and dipping to the south-east is overlaid by the Lower Coal Measures of Denholme Park. The Rough Rock is again thrown down by the fault through Cuckoo Park, forms Brow Moor and extends as far northwards as the fault through Cullingworth, which has been already referred to. It also occurs as an outlier on Harden Moor. In the country lying south-east of Harden Beck, the triangular space lying between two faults south of Wilsden, is occupied by Rough Rock, which finally, on the downcast side of the fault passing through Wilsden, runs down into the valley of the River Aire to the north of Cottingley. South of this village it is again overlaid by Coal Measures.

Between Airedale and Wharfedale the Rough Rock forms the highest escarpment above Ilkley on Ilkley Moor, and dipping away towards the south and south-east forms the surface rock over a large portion of the moors north of Baildon. East of the Guiseley Valley the Middle Grits are overlaid by this rock at Yeadon Moor, and again at Crag House.

A belt of east and west faults range from Dean Grange Farm through Henshaw and Baildon Common. These faults are generally downcasts to the south. They bring in the outliers of Lower Coal Measures, which occur on the north side of the River Aire, and form the northern boundary to both the Baildon and Rawden Outliers.

Between Bingley and Baildon the Rough Rock forms the bold escarpments of Gilstead Moor and Baildon Bank; while the Middle Grits appear lower down on the flank of the hill. The grits are succeeded by the Lower Coal Measures, which form

the outlier, and contain all the beds up to the "Sixty-Yards Quarrell."

The main portion of the Ganister Beds, however, lies to the south of the Aire Valley. From the dip-slope of the Rough Rock between Denholme Park and Thackley, the ground rises in a general, though somewhat irregular, north-easterly direction, and is intersected by valleys, and broken by numerous faults. Along this ridge the various members of the Lower Coal Measures, Nos. 37, to 50, come on in gradual succession from Denholme Park, through Denholme, Cottingley Moor, Shipley Moor, and Wrose Hill to Thackley.

From the ridge at Denholme Park, the measures which lie between the fault passing through Leeming to Thornton Lane End, and the fault through Cullingworth to Bradford stretch away south-westwards to the last named town. One or other of the rocks belonging to the Elland Flagstone Group, caps the tops of the ridges and occupies most of the higher ground within this tract of country. It is only on the Bowling side of the Bradford Valley that beds up to, and including, the Crow Coal are reached.

The two faults, which stretch eastwards from Chellow Dean in a curved line traversing the northern part of the town of Bradford to Undercliffe, enclose a patch of ground in which occur a portion of the highest measures of the Ganister Beds found in this district. The most northerly of these faults is an upthrow to the north, and from Bradford this fault ranges in a general north-direction through Calverley. North of this fault, and stretching west from Wilsden to Thackley, the different members of the Flagstone Group form the distinctive features of, and occupy considerable tracts in, the country on both sides of the Bradford valley. Within two small areas on the east side of the valley, measures as high up in the series as the Better Bed Coal occur. This coal also caps the top of the ridge at Undercliffe. This portion of country is intersected by a number of faults, and at Thackley a fault which runs south-east through Thorpe brings up the Rough Rock and Lower Coal Measures from Thackley to Calverley. Within the space between this fault and the belt of east and west faults before alluded to, occur the different members of the Millstone Grit Series from the upper beds of the Middle Grit to the Rough Rock. The Rough Rock is overlaid north of the River Aire, by the Ganister Beds forming portion of the Rawden outlier; and the Sixty-Yards Rock caps the top of the hill north of the village.

On the south-east side of the fault running through Calverley another fault, approximately parallel to it, ranges north-east from Bradford. This fault is a downcast to the north-west. These two faults enclose a belt of country which connects the Rawden outlier with the northern edge of the coal-field. This belt of country contains all the beds from the Soft Bed Coal up to the measures above the Crow Coal.

The remaining area consists of two tracts, one lying mainly north, and the other south, of the River Aire. The northern portion is chiefly occupied by the various beds of Millstone Grit, from the topmost member of the Middle Grit upwards. The grits are followed west of Horsforth by the Lower Coal Measures, which form the eastern portion of the Rawden outlier, and include the 32-Yards Rock. The southern portion is mainly occupied by the measures from the top of the Rough Rock up to and including the Elland Flagstone. The flagstone forms the principal features and covers the tops of some of the highest ridges. In a very few instances only, do beds as high in the series as the Better Bed and Black Bed Coals occur in this district.

INDEX.

Addingham, 13.
 Addingham Edge, 6, 7, 15.
 Alluvium, 3, 4, 12, 13.

Baildon, 8, 13, 15.
 Beamsley, 14.
 Better Bed Coal, 4, 10, 16, 17.
 Better Bed Seat-stone, 4.
 Bingley, 12, 15.
 Black Bed Coal, 4, 10, 17.
 Black Moor, 15.
 "Blue Stone," 8, 15.
 Bowling, 16.
 Bradford, 9, 10, 16.
 Bramhope, 7.
 Burley, 12.

Calder Valley, 6, 13.
 Calverley, 16.
 Carlton Limestone, 14.
 Chatsworth Grit, 14.
 Chellow Dean, 16.
 Coal Measures, 4, 5, 7-11, 15-17.
 Colne Valley, 6.
 Cononley, 14.
 Cottingley, 15, 16.
 Cottingley Crow Coal, 4, 9.
 Crow Coal, 4, 11, 16.
 Crow Croft Coal, 5, 8.
 Cuckoo Park, 15.
 Cullingworth, 15, 16.

Denholme, 9, 10, 15, 16.
 Derbyshire, 6, 14.
 Drainage, 13.
 Draughton, 14.

Earl Crag, 6, 14.
 Earl Crag Grit, 5, 7, 13, 14.
 Economics, 7, 9-11.
 Elland Flagstone, 4, 10, 16, 17.
 Esholt, 13.
 Eskers, 3, 4, 12.

FARREY, J., 6.
 Farfield, 14.
 Farnhill Moor, 14.
 Farnhill Moor Coal, 5, 7.
 Faruley, 11.
 Fireclay, 4, 9, 10.

Gaisby Rock, 4, 10.
 Galliard or Ganister, 4, 9.
 Gilstead Moor, 8, 15.
 Glacial Drift, 3, 4, 11, 13.
 Glusburn, 14.

Goniatices, 8.
 Guiseley Grit, 5.

Hallan Hill, 6.
 Hard Bed Band Coal, 4, 10.
 Hard Bed Coal, 4, 9, 10.
 Harden, 12, 15.
 Hawkesworth, 12.
 Haworth, 6, 8.
 Heaton, 9.
 Henshaw, 15.
 High Bradley Coal, 5, 7.
 Horsforth, 8, 9, 17.
 Hunsworth, 10.

Idle, 8, 9.
 Ilkley, 12, 13, 15.
 Ironstone, 4, 11.

Keighley, 8, 12, 13, 15.
 Kinder Scout Grit, 5-7, 14.

Laister Dyke, 10.
 Lead Ore, 14.
 Leathley Sandstone, 5.
 Leeming, 15, 16.
 Limestone Shales, 3-6, 14.
 Lithology, 6, 13.
 Low Bradley Coal, 5, 7.
 Low Moor, 10.

Middle Band Coal, 4, 9.
 Middle Band Stone, 4, 9.
 Middle Grits, 5-8, 14, 15, 17.
 Millstone Grit, 3-8, 14, 15, 17.
 Morton Banks Coal, 5, 8.

Nab, 6, 8, 15.
 Newlay, 13.

Oakworth, 15.
 Otley, 13.
 Otley Chevin, 6, 7, 15.
 Oxenhope, 6, 8, 13, 15.

Peat, 4, 13.
 Pendle Hill Grit, 5, 6, 14.
 Physical Features, 13.
 Plompton Grit, 7.
 Ponden, 15.
 Poole, 13.
Posidonomya, 5.
 Post-Tertiary, 3, 4, 11-13.

Rawden, 9, 15-17.
 Rough Rock, 5, 8, 15-17.

- Shipleigh, 12, 16.
Silsden, 7, 8.
Sixty-yards Quarrell (Rock), 4, 10, 16.
Skipton, 3, 14.
Soft Bed Coal, 4, 9, 16.
Soft Bed Seat-stone, 9.
Stanbury, 13, 15.
Stanbury Moor Coal, 5.
Stanningley, 9.
Steeton, 14.
Stratigraphy, 14-17.
Sutton, 14, 15.

Table of Formations, 4, 5.
Thackley, 16.
"Thick Stone," 4.

Third Grit, *see* Middle Grits.
Thirty-two Yards Rock, 4, 9, 10, 17.
Thornton, 9, 10, 15, 16.
Thorpe, 16.

Undercliffe, 16.
Upper Grit, *see* Rough Rock.
Utley, 15.

Weston Grit, 5.
White Crag, 15.
Wilsden, 15, 16.
Wortley, 10.
Wrose Hill, 16.

Yeadon, 15.
-



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 Bristol and Somerset, 19, 35.
 Coalbrook Dale, 61 (NE & SE).
 Cleve Hill, 53 (NE, NW).
 Denbighshire, 74 (NE & SE), 79 (SE).
 Derby and Yorkshire, 71 (NW, NE, & SE), 82 (NW & SW), 81 (NE), 87 (NE, SE), 88 (SE)
 Durham, 105.
 Flintshire, 76 (NE & SE).
 Forest of Dean, 43 (SE & SW).
 Forest of Wyre, 61 (SE), 55 (NE).
 Lancashire, 80 (NW), 81 (NW), 89 (SE, NE, NW, & SW), 88 (SW). (For corresponding six-inch Maps, see detailed list.)
 Leicestershire, 71 (SW), 63 (NW).
 Northumberland and Durham (N. part), 105 (NE & SE).
 North Staffordshire, 72 (NW), 72 (SW), 73 (NE), 80 (SE), 81 (SW).
 South Staffordshire, 54 (NW), 62 (SW).
 Shrewsbury, 60 (NE), 61 (NW & SW).
 South Wales, 36, 37, 38, 40, 41, 42 (SE, SW).
 Warwickshire, 62 (NE & SE), 63 (NW & SW), 54 (NE), 53 (NW).
 Yorkshire, 88, 87 (SW), 93 (SW), &c.

SCOTLAND.

*Edinburgh, 32, 33. *Haddington, 32, 33.
 Fife and Linross, 40, 41, &c. &c.

IRELAND.

*Kanturk, 174, 175. *Castlecumber, 128, 137.
 Killenare (Tipperary), 146.
 (For Sections illustrating these Maps, see detailed list.)
 * With descriptive Memoir.

GEOLOGICAL MAPS.

Scale, six inches to a mile.

The Coalfields of Lancashire, Northumberland, Cumberland, Westmorland, Durham, Yorkshire, Edinburghshire, Haddington, Fife, Renfrewshire, Dumbartonshire, Dumfriesshire, Lanarkshire, Stirlingshire, and Ayrshire are surveyed on a scale of six inches to a mile.

Lancashire.

47. Clitheroe.	89. Rochdale, &c.
48. Colne, Twiston Moor.	92. Bickerstaffe, Skelmersdale.
49. Laneshaw Bridge.	93. Wigan, Up Holland, &c.
55. Whalley.	94. West Houghton, Hindley, Atherton
56. Hasgare. 6s.	95. Radcliffe, Peel Swinton, &c.
57. Winewall.	96. Middleton, Prestwich, &c.
61. Preston.	97. Oldham, &c.
62. Balderstone, &c.	100. Knowsley, Rainford, &c.
63. Accrington.	101. Billinge, Ashton, &c.
64. Burnley.	102. Leigh, Lowton.
65. Stiperden Moor. 4s.	103. Ashley, Eccles.
69. Layland.	104. Manchester, Salford, &c.
70. Blackburn, &c.	105. Ashton-under-Lyne.
72. Cliviger, Bacup, &c.	106. Liverpool, &c.
73. Todmorden. 4s.	107. Prescott, Huyton, &c.
77. Chorley.	108. St. Helen's, Burton Wood.
78. Bolton-le-Moors.	109. Winwick, &c. 6s.
79. Entwistle.	111. Cheedale, part of Stockport, &c.
80. Tottington.	112. Stockport, &c. 4s.
81. Wardle. 6s.	113. Part of Liverpool, &c. 4s.
84. Ormskirk, St. John's, &c.	
85. Standish, &c.	
86. Adlington, Horwick, &c.	
87. Bolton-le-Moors.	
88. Bury Heywood.	

Durham.

Scale, six inches to a mile.

Sheet.	Sheet.
1. Ryton. 4s.	8. Sunderland.
2. Gateshead. 4s.	9. ———— 4s.
3. Jarrow. 4s.	10. Edmond Byers. 4s.
4. S. Shields. 4s.	11. Elcheater.
5. Greenside. 4s.	12. Lantofdy.
6. Winaaton.	13. Chester-le-Street. 6s.
7. Washington.	14. Chester-le-Street.

Durham—cont.

Sheet.	Sheet.
15. Hunstanworth.	25. Wolsingham.
17. Waskerley.	28. Brancepeth.
18. Muggleswick.	32. White Kirkley.
19. Lancaster. 6s. Vertical Section, 3s.	33. Hamsterley.
20. Hetton-le-Hole.	34. Whitworth.
24. Stanhope.	41. Crockfield.
	42. Bishop Auckland.

Northumberland.

Scale, six inches to a mile.

47. Coquet Island. 4s.	88. Long Benton.
56. Druridge Bay, &c.	89. Tynemouth.
83. Netherwitton.	92. Haltwhistle.
65. Newbiggin. 4s.	95. Corbridge.
68. Bellingham.	96. Horsley. 4s.
69. Redesdale.	97. Newcastle-on-Tyne. 4s.
72. Bedlington.	98. Walker. 4s.
73. Blyth. 4s.	101. ————
77. Swinburn.	102. Allendale Town.
79. Ingoe. 6s.	105. Newlands.
80. Cramlington.	107. Allendale.
81. Earsdon.	108. Blanchland.
84. Newborough.	109. Shofield.
85. Chollerton.	110. Wellhope.
86. Matfen.	111. Allenheads.
87. Heddon-on-the-Wall.	

Yorkshire.

100. Limley.	274. Barnsley.
184. Kelbrook.	275. Darfield.
201. Bingley.	276. Brodsworth.
204. Aberford.	281. Langsall.
216. Bradford.	282. Wortley.
217. Calverley.	283. With upon Dearne.
218. Leeds.	284. Conisborough.
219. Kippax.	287. Low Bradford.
231. Halifax.	288. Ecclesfield.
232. Birstal.	289. Rotherham.
233. East Ardsley.	290. Braithwell.
234. Castleford.	293. Hallam Moors. 4s.
246. Huddersfield.	295. Handsworth.
260. Honley.	296. Loughton-en-le-Morthen.
272. Holmfirth.	299. ————
273. Penistone.	300. Harthill.

SCOTLAND.

Scale, six inches to a mile.

Edinburghshire.

2. Edinburgh, &c.	12. Penicuik, Coalfields of
3. Portobello, Musselburgh, &c.	Lasswade, &c.
6. Gilmerton, Burdie House, &c.	13. Temple, &c.
7. Dalkeith, &c.	14. Pathead. 4s.
8. Preston Hall. 4s.	17. Brunston Colliery, &c.
	18. Howgate.

Haddingtonshire.

Scale, six inches to a mile.

8. Prestonpans, &c. Price 4s.
9. Trenant, Gladsmuir, &c. Price 6s.
13. Elphinstone, &c. Price 4s.
14. Ormiston, East Salton, &c.

Fife.

Scale, six inches to a mile.

24. Markinch, &c.	33. Buchhaven.
25. Seconie, &c.	35. Dunfermline.
30. Beath, &c.	36. Kinghorn.
31. Auchterderran. 4s.	37. Kinghorn. 4s.
32. Dysart, &c.	

Ayrshire.

Scale, six inches to one mile.

19. Newmilns.	36. Grieve Hill.
26. Glenbuck. 4s.	40. Chiltree.
27. Monkton, &c.	41. Dalcaeglar.
28. Tarholton, &c.	42. New Cumnock.
30. Aird's Moss.	43. Dalmellington.
31. Muirkirk. 4s.	47. Benheck.
33. Ayr, &c.	50. Daily.
34. Coynton.	52. Glenmoat.

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